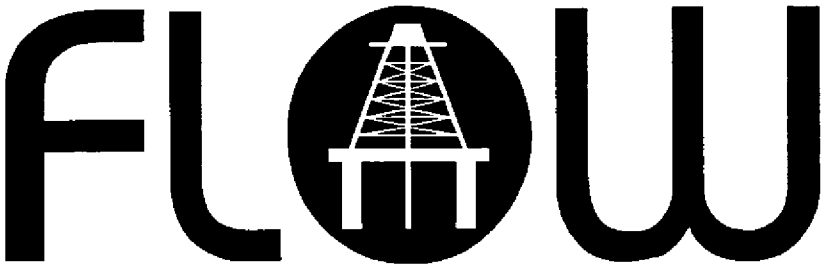
North Sea



Measurement Workshop

1998

PAPER 29

FOCUS DISCUSSION GROUP F

MEASUREMENT UNCERTAINTY

M Basil, Flow Ltd

The Application of Monte Carlo Simulation to Measurement Uncertainty

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Overview

- Background
- Explanation
- Example
- Applications

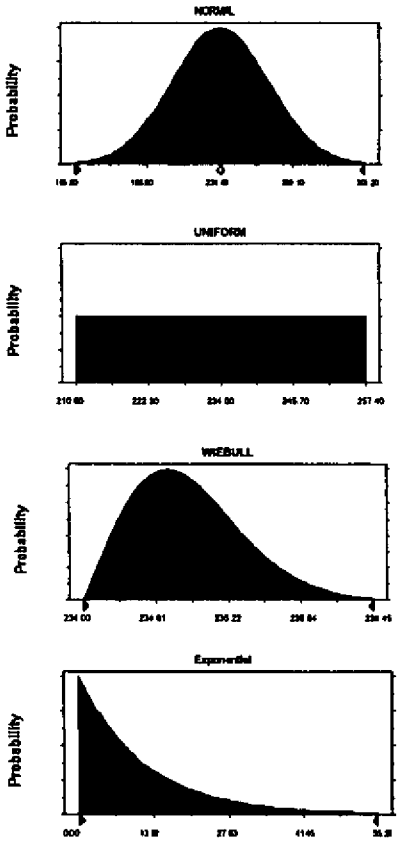
Background

- Wide use for risk analysis in business and industry
- First used in 1908 to confirm Student t-distribution
- First applied on the "Manhattan Project"
- Only method to solve some classes of problem
- Use limited by need for fast computers

- Widely used in business and on large projects for risk assessment and decision making
- First practical application in 1908 by William Sealy Gosset (Student) in the discovery of the correlation coefficient and later the same year to confirm his Student t-distribution findings
- First real application stems from development of the atomic bomb "Manhattan Project" during the second world war
- Until recently the need for fast computers has prevented wider application in areas such as uncertainty assessment
-

Explanation 1 Input Sensors

- Simulate measurement sensors
- Inputs may have any distribution
- Typically a "normal" distribution...
- ...with a "mean"
- ...and "standard deviation" based on the measurement uncertainty at a 95% confidence level i.e. 2 std. dev.



Explanation 2 Model

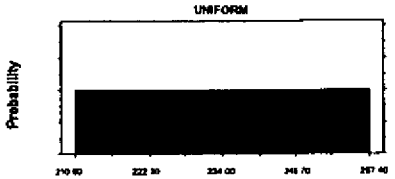
- **Simulated input sensor values are applied to a mathematical model of the measurement system**

$$x = a + b^2$$

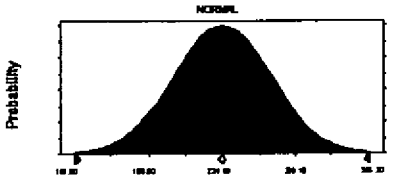
- **Repeated until sufficient trials representing most combinations of sensor values**

Explanation 3 System Output

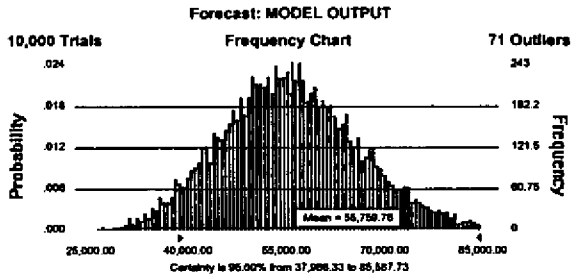
a



b



$$x = a + b^2$$



x

Measurement System Output Uncertainty is found from the "mean" and "standard deviation" of the distribution X

i.e. Uncertainty at 95% confidence level = 2 std. dev.

Example Analytical Uncertainty

Stream 1

Gas orifice plate flow meter

Q_1= 10mmscfd

E_1=1%

Stream 2

Gas orifice plate flow meter

Q_2= 10mmscfd

E_2=1%

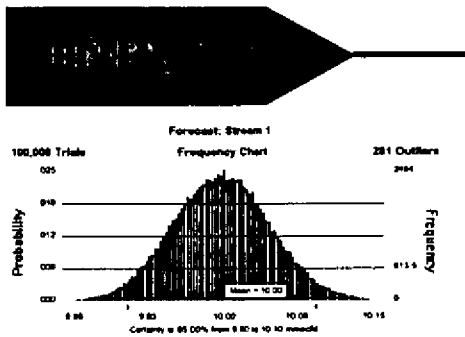
Total Gas

$Q_T = Q_1 + Q_2$=20mmscfd

$$E_T = \frac{\sqrt{(E_1 \cdot Q_1)^2 + (E_2 \cdot Q_2)^2}}{Q_T} \%$$

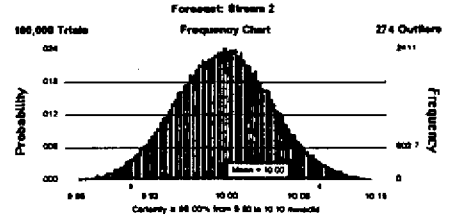
E_T=0.7071%

Example Monte Carlo Uncertainty



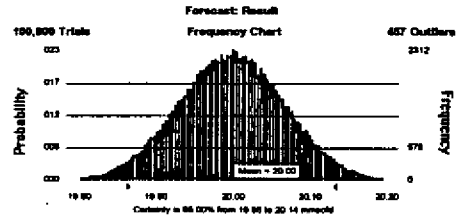
Q_{1MCS}= 9.999770mmscfd

E_{1MCS}=1.00171%



Q_{2MCS}= 9.999913mmscfd

E_{2MCS}=0.99972%



Q_{TMCS}= 19.999682mmscfd

E_{TMCS}=0.70753%

Applications

- Verification of analytical methods
- Large number of inputs or outputs
- Complex calculations and Non-linear relationships
- Large measurement uncertainty i.e. MPM
- Dependant inputs
- Unconventional input or output distributions